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REPORT OF A SPECIAL COMMITTEE ON THE CORRELATION OF THE PRE-CAMBRIAN ROCKS OF THE ADIRONDACK MOUNTAINS, THE "ORIGINAL LAURENTIAN AREA" OF CANADA, AND EASTERN ONTARIO

To C. Willard Hayes, Charles R. Van Hise, Albert P. Low and Frank D. Adams, General International Committee on Geological Nomenclature, Representing the Geological Surveys of the United States and Canada:

I. INTRODUCTION

At a meeting of the International Committee on Geological Nomenclature, representing the Geological Surveys of the United States and Canada, held at Ottawa, Canada, on December 31, 1905, it was decided that the subcommittee on the correlation of the pre-Cambrian rocks of the Adirondack Mountains, the original Laurentian area and of eastern Ontario, consisting of President C. R. Van Hise and Professor Frank D. Adams, which had been appointed at the first meeting of the committee, held in Washington on January 2, 1903, should be enlarged by the addition of Professor A. P. Coleman and Professor J. F. Kemp, and that Dr. J. M. Clarke, State Geologist of New York, should be invited to appoint a representative on this committee. Dr. Clarke was subsequently consulted, and appointed Professor H. P. Cushing as representative of the Geological Survey of the State of New York. Dr. Robert Bell was also invited to join the subcommittee. On July 4, when the committee assembled to begin its work, Dr. Bell, being in Europe, was unable to take part in the work of the committee, and his place was taken by Dr. A. E. Barlow, of the Geological Survey of Canada. Dr. Barlow, however, was able to remain in the field only during a period of about ten days when the committee was at work in the Adirondack Mountains.

Dr. A. W. Spencer, of the United States Geological Survey, accompanied the committee from July 6 to July 23.

This special committee met at Whitehall, N. Y., on July 4, and spent the month of July, 1906, in visiting various districts in the Adirondack Mountains and in the eastern portion of Ontario, with the view of ascertaining, if possible, whether they could agree upon the succession and correlation of the great exposures of pre-Cambrian rocks in these areas, and also upon the nomenclature which should be adopted in the classification of the same.

The mapping of the eastern Adirondack area is now being carried on by J. F. Kemp, and that of the northern Adirondack area by H. P. Cushing and C. H. Smyth, but this work is not as yet completed.

The area visited by the committee in Canada was for the most part that whose mapping has just been completed by F. D. Adams and A. E. Barlow, and which is comprised in the Haliburton and Bancroft sheets of the Ontario series of geological maps being issued by the Geological Survey of Canada, printed copies of the maps in question being supplied to the members of the committee when in the field. The geological report on this area, however, has not as yet been published.

The committee also visited, while in Canada, the Madoc region, which lies to the south and southeast of the area mapped by F. D. Adams and A. E. Barlow. This area was in the early years of the Canadian Survey mapped by Mr. H. G. Vennor, and a portion of it was at a later date mapped on a larger scale by Mr. Eugene Coste.

In making the present report, therefore, the committee wish it to be distinctly understood that in it they are not presenting any new observations made by them in the areas visited, but are merely recording certain facts pointed out to them by Dr. Kemp and Dr. Cushing in the Adirondack area, and by Dr. Adams in eastern Ontario, which will be described in detail in the forthcoming reports by these several gentlemen. To the interpretation of these facts by the gentlemen in question the committee give their full assent, and upon them base their recommendations for the correlation of these rocks in the several areas under discussion.

II. ITINERARY OF THE COMMITTEE

A. ITINERARY IN THE EASTERN ADIRONDACKS

(Under the guidance of J. F. KEMP)

The committee was summoned to meet in Whitehall, N. Y., on the night of July 4. The first week was devoted to areas which had been mapped by J. F. Kemp in or near the Champlain valley. July 5 the committee, represented by Messrs. Adams and Kemp, reviewed first the green syenitic gneiss in the southwestern portion of Whitehall village, where a massive eruptive rock has become so granulated and platy from crushing and shearing that it strongly resembles sandstone and is quarried like a stratified sediment. Next in the railway cuts north of Comstocks, garnetiferous, thinly foliated, micaceous gneiss was seen, which is believed to be sedimentary. The gneiss was penetrated both by red granite, now rolled out into thinly foliated gneiss with many leaves of quartz, and by a stock or small laccolith of gabbro, which had produced extraordinary rolls in the foliation. Two miles south of Comstocks and just east of the canal two strata of white, crystalline limestone were exposed, of which the lower is seventy-five feet thick, the upper much less. The limestones are associated with black hornblendic gneisses and with granitic gneisses of whose nature, whether sedimentary or igneous, it was not possible to positively decide. From their mineralogical composition they might be either, but the almost constant association with the limestones throughout the area creates a presumption in favor of sediments. The limestone exhibited interesting results of dynamic effects, in dragged and squeezed inclusions of hornblendic schist. In the area between the limestones and Comstocks was the basal Potsdam in a thin coat over the gneiss.

The following day Messrs. Coleman, Cushing, and Spencer joined the others in Whitehall, and all proceeded by the north road across the neck between Lake Champlain and South Bay. The party observed the syenitic gneiss which is believed to penetrate the rusty and somewhat calcareous sedimentary gneisses, and were impressed with the faulted nature of the topography. Crossing

South Bay they traversed platy quartzose, garnetiferous, sedimentary gneisses, with intrusions of gabbro and trap dikes. They observed in the gneiss a development of graphitic schist which has been mined. Proceeding several miles up Pike Brook, the party crossed an outlier of Potsdam sandstone faulted down between the hills of gneiss, and to the southwest on the old State Road saw a ledge of about forty feet of graphitic schist capped by gabbro. Returning, they recrossed South Bay and went over the high ridge to Whitehall, crossing doubtful gneisses, believed, however, to be probably sedimentary. The same evening the party moved to Ticonderoga.

From Ticonderoga, on the following morning, the committee proceeded to Hague on Lake George, and visited the Lakeside graphite mine, where a graphitic quartzite six to ten feet thick is inclosed in garnetiferous, sillimanite gneiss. Still lower are gneisses of quartzose, feldspathic composition. The party then rowed to Flirtation Island, north of Hague, where a gneiss which closely resembles a conglomerate was finally interpreted as one injected with pegmatite stringers and subsequently squeezed. Farther north at Indian Kettles Point a massive, garnetiferous granitic gneiss was seen which was believed to be intrusive. Returning to Hague, the steamer was taken to Rogers Rock, and the party climbed Rogers Slide, a summit about 850 feet above the lake. They crossed much white crystalline limestone, charged with silicates, graphitic pegmatites, and rusty gneisses, until toward the summit they passed to decidedly massive garnetiferous granitic gneiss, similar to the exposures on Indian Kettles Point. All were impressed with its igneous affinities, and attributed the garnets to the influence and contributions of the neighboring limestones. The rock is believed by J. F. Kemp to be an acidic phase of the syenitic eruptives which are normal and abundant in the vicinity. Proceeding to Ticonderoga on foot, the party traversed typical green syenite at the outlet of Lake George, and had no doubt of its eruptive nature.

The next morning the party moved to Port Henry and walked north on the tracks of the railway on the shores of Lake Champlain. Passing across faulted blocks of Beekmantown and perhaps upper Potsdam, they encountered a large intrusion of gabbro. At first gneissoid on the south, the gabbro passes gradually into more massive phases until it is coarsely diabasic in texture. The gabbro is succeeded by a thick ledge of white crystalline limestone, into which it tongues out with various small apophyses. The limestone is charged with streaks and bunches of silicates, which are contorted in so extreme a degree as to give truly remarkable results of pressure. Farther north quartzose gneisses and more gneissoid gabbro were traversed, the former greatly brecciated by faulting. From the railway the party climbed the hill to the old Cheever magnetite mine and its northward extension. The ore is found as an extended bed, sometimes double, and a half mile or more in length. It is contained in a gneiss, of granitic composition, which has gabbro a short distance below and white crystalline limestone a short distance above. Various opinions were advanced about the nature of the gneiss and the origin of the ore, sedimentary, intrusive, and contact views being all expressed without reaching unanimity. Returning by highway to Port Henry, the party visited the ophicalcite and white limestone quarries lying to the west of the road, and saw the latter rock much cut up by pinched pegmatites and basic stringers.

The following day the committee drove to Mineville, six miles northwest, and on the way visited another quarry in white limestone and the abandoned Pilfershire magnetite mines. The relations of the ore are much the same as at the Cheever, except that heavy drift so masks the exposures below the gneiss forming the wall-rock that their nature cannot be told. At Mineville the party visited the great iron mines and studied the relations with the overlying acidic gneiss and the underlying, generally basic, hornblendic variety. At the belt of ore on Barton Hill it was shown that the underlying hornblendic gneiss passed directly into gabbro. Various views were suggested for the formation of the ore, some favoring igneous segregation, others contact metamorphism, still others replacement or sedimentation; but the problem was too obscure for agreement. In the evening the party was joined by C. R. Van Hise and A. E. Barlow.

The following day the committee again went over the mines and examined the maps which were courteously shown by the chief engineer of the company, and later visited the outlying workings at Cook Shaft and Fisher Hill. The general feeling was that several successive processes might have been involved in producing the ore in its present form. In the evening all moved to Plattsburg, where H. P. Cushing became the guide.

In the eastern Adirondacks the attempt was made to visit the rocks of actual or probable sedimentary character, rather than the great eruptives of whose nature there is much more certainty.

B. ITINERARY IN THE NORTHERN ADIRONDACKS

(Under the guidance of H. P. CUSHING)

On July 11 the party went from Plattsburg to Tupper Lake, with stops at Dannemora and Saranac. At Dannemora amphibolites were seen, cut by granitic gneisses, and both cut by unmetamorphosed dikes of diabase and syenite porphyry. The locality was typical of a great area in the northern Adirondacks where such a gneiss complex prevails, along with frequent gray gneiss of intermediate composition. The origin of the amphibolite is uncertain. The complex has been called the Saranac gneiss and is precisely like that seen later in many places in Canada.

At Saranac a locality was visited which showed irruptive contact of anorthosite with gneisses which, while themselves of somewhat doubtful nature, are in close association with undoubted Grenville sediments near at hand.

The following day the party drove from Tupper Lake to and through Litchfield Park, seeing the gradation from the typical green syenite along the lake to the reddish, granitic phase of the same rock in the park, and seeing also the red granites, almost wholly quartz-feldspar rocks, which cut the syenite. A small anorthosite outlier was also visited. This is surrounded on all sides by the red syenite, which, as the anorthosite is neared, grades into a basic green syenite which cuts the anorthosite, though the best locality for seeing this was not located. Adams did not accompany the party on this day.

July 13 the committee drove from Tupper Lake to Axton, seeing first green syenite, followed after an interval with no exposures by anorthosite cut up by dikes of varying sizes of a rock which H. P. Cushing believes to be the syenite, and which seemed such to the other members of the party except A. W. Spencer, who expressed some doubt as to the equivalence. Beyond, the route was entirely in anorthosite, of somewhat gabbroic nature for the most part. Panther Mountain, at the south end of Upper Saranac Lake, which was climbed by the party because of the good view of the general topography of the region obtainable from its summit, furnished a good exhibition of the general character of the anorthosite. Syenite dikes of various sizes persist in the anorthosite with diminishing frequency for a distance of three or four miles from the edge of the mass.

The next day boats were taken at Axton for a trip down the Raquette to Tupper Lake, with a side excursion into Follensby Pond. The anorthosite was found grading from the normal rock at Axton into a basic gabbro near Follensby Pond, adjoined by the syenite in somewhat basic phase, illustrating the general tendency of the anorthosite bathylith to become more basic at its borders, and the similar tendency of the syenite to become more basic in the vicinity of the anorthosite. At the upper end of Follensby Pond Grenville rocks were seen, the outcrops being at the northern extremity of a long belt of these rocks extending unbroken for several miles. Limestone, both pure and impure, rusty graphitic gneiss, and a little quartzite were seen. These and other rocks of the belt are precisely like those seen the preceding week and those seen later in Canada. Down the river from Follensby the rocks seen were anorthosite of the gabbro type followed by syenite.

The rocks of the central area of the Adirondack region consist mainly of bathyliths and smaller masses of anorthosite, syenite, granite, and gabbro, with only occasional patches of the sediments, and the region seen in the three days was a good sample of the general area. The asymmetric differentiation of the syenite into a basic type in the vicinity of the anorthosite, which it cuts, and into an acid type in the contrary direction where it adjoins and cuts granitic gneisses, as well as the local differentiation of the acid syenite into the basic type around an inclusion of anorthosite, seemed to point to the digestion of material from the adjacent rocks as a cause of the differentiation.

Monday, July 16, was mainly taken up in journeying from Tupper Lake to Theresa in Jefferson County, to see there the rocks as they appear in the northwestern region. The evening of July 16 and the whole of the next day were spent in this examination. A thick limestone formation was seen, and a great thickness of other rocks in thinner beds, including limestones, quartzites, amphibolites, and various gneisses, all of which were cut by dikes and small bosses of granite. The series seems to be sharply folded—so sharply that the prevailing dips are in one direction. The thick limestone was found to be overlain by a great mass of granitic gneiss, under which it seemed to dip, and with no sign of contact action in the limestone, though there were traces of it in the edge of the granite. Some varieties of gneiss somewhat suggest tuffs. The Potsdam is just being worn away from the pre-Cambrian with many patches of it, both large and small, yet in position, showing various conglomerates and a very irregular deposition floor. Near at hand, but not visited, is a large granite bathylith full of amphibolite inclusions, precisely like those seen later near Deloro and Gooderham.

In the evening the party went to Clayton.

C. ITINERARY IN EASTERN ONTARIO

(Under the guidance of F. D. ADAMS)

The committee then crossed the St. Lawrence into Canada, taking the ferry from Clayton to Kingston, from which latter place they went by train to Tweed.

From here they proceeded to Bridgewater, in order to examine certain conglomerates referred to by Vennor. About half a mile east of Bridgewater they found granite protruding through the drift, which granite was succeeded immediately to the west by a body of amphibolite. In the amphibolite an autoclastic structure was developed in places, which gave rise to an appearance faintly simulating a conglomerate. All the members of the committee, however, agreed that this structure was autoclastic and was of no stratigraphical significance.

Passing by a great development of crystalline limestone with interstratified bands of fine-grained gneissic rocks at the village of Bridgewater, the committee went to a point one and a half miles west of this village, where they found exposed by the side of the road a conglomerate which is undoubtedly of true clastic origin.

This conglomerate is exposed for several miles along the Madoc road, which runs east and west, and a good cross-section of the conglomerate and the strata with which it is associated was found on the Queensboro road, which crosses the Madoc road at right angles. The conglomerate contains very numerous pebbles of several different kinds of rock. These are as follows:

1. Pink felsite. These are most abundant and form the dominant element of the conglomerate.
2. White quartz, resembling vein quartz.
3. White quartzite.
4. Amphibolite, dark in color and very fine in grain.

To the west of the Queensboro road the conglomerate also holds some pebbles of cherty and ferruginous rocks resembling those found in the iron ranges of the Lake Superior district.

The pebbles of this conglomerate are often quite round, but are usually very considerably flattened. They are sometimes several inches in diameter. The rock shows very considerable variations in size and abundance of the pebbles in different bands, some bands being entirely free from pebbles and resembling a quartzite in appearance. The conglomerate also shows distinct cross-bedding in certain places. It has a nearly vertical attitude, its beds being bent back upon themselves in a series of sharp folds.

On the Queensboro road, to the south of its intersection with the Madoc road, the conglomerate is followed by a dark amphibolite containing a great number of small corrugated quartz veins, presenting a remarkable autoclastic structure and often pinched out into forms closely resembling pebbles. This is succeeded by a series of pink felsites, which in their turn are followed by calcareous amphibolites, and these by crystalline limestones.

The succession on the Queensboro road from north to south, with the approximate thickness of the several occurrences (as exposed), is as follows:

Dark amphibolite, for the most part massive	600	feet +
Conglomerate (probably duplicated by folding)	3,100	"
Amphibolite with quartz veins showing autoclastic structure	?	
Pink felsites	352	"
Calcareous amphibolite	935	"
Crystalline limestone	300	" +

Before the conglomerate was laid down it is certain that the crystalline limestone, the calcareous amphibolite, and the pink felsites were in a condition to yield fragments, that such fragments were well rounded by water action, and that these formations were the chief sources of material for the conglomerate. It therefore follows that there is an important local break between the conglomerate and the underlying formations. However, the district is one in which contemporaneous volcanic action occurred, and when the conglomerate is traced along the strike it appears to contain volcanic clastic material. The question therefore arises whether this conglomerate marks a general uncomformity in the sedimentary series for the district or is a local unconformity. This question can be finally decided only when the Madoc district is mapped in detail.

The committee then went to Deloro, which lies about seven miles to the west of the village of Madoc. In this vicinity they found a large mass of granite, constituting what is locally termed the "Huckleberry Rocks," penetrating a series of highly altered impure crystalline limestones and developing in the latter a great variety of silicates in the form of irregular bands and masses.

A short distance to the north of the village of Deloro the granite was found cutting a dark amphibolite, of which it inclosed an immense number of angular fragments which in places presented distinct evidence of being absorbed by the granite mass. It was not quite clear whether this process of absorption was produced by the complete solution of the amphibolite in the granite and the subsequent recrystallization of the resulting mass, or whether the intermediate rock had resulted from a very complete penetration of the intruded amphibolite by granitic material. According to Mr. Coste, the amphibolite in question results from the alteration of the limestone by the granite mass, but the limited time at the disposal of the committee did not permit them to examine a sufficient area to enable them to satisfy themselves on this point. Some of the amphibolitic masses included in the granite, however, had the appearance of tufaceous material—a fact which is of importance in connection with the question of the origin of the amphibolite as a whole. The committee considers that this granite intrusion presents one of the finest known examples of both exomorphic and endomorphic contact action.

The committee then went north to the village of Bannockburn, about a mile to the southwest of which, on the road, they found a great body of massive diorite or amphibolite in contact with the same limestone series, the two rocks being folded together along their contact. The appearance of this dioritic mass near Bannockburn suggests somewhat, in the traces of ellipsoidal structure which it presents, certain Keewatin rocks of the Lake Superior region.

The committee then visited the district about Millbridge on the Hastings road, where they again found the same limestone series which here, being very free from igneous intrusions, is comparatively unaltered in character and preserves its original blue color. This body of limestone, however, although apparently uniform in character, is seen, on a careful study, especially of the weathered surface to contain many thin, interstratified layers which are much harder than the limestone itself, and which when examined under the microscope are found to be composed almost entirely of silicates, chiefly feldspars, both plagioclase and orthoclase, with quartz and some biotite. The rock composing these layers now shows a perfect "pflaster" or pavement structure, and is completely crystalline. It is, however, of undoubtedly sedimentary origin and has been referred to by Adams as "paragneiss". These bands are of importance as representing in this comparatively unaltered portion of the limestone formation rocks which, when the alteration of the formation is more pronounced, assume a much more distinctive form.

From Millbridge the committee went north on the Hastings road, which, running at right angles to the strike of the rocks, affords a most admirable section through the sedimentary series with its various interstratified rocks, for a distance of thirty miles north of Millbridge, where the sedimentary series becomes torn to pieces by the great invasions of the granite bathyliths to be mentioned later.

About three miles to the north of Millbridge a great intrusion of more or less altered gabbro, about two miles in width, was crossed. This was found to be nearly massive in character and to alter the intruded sedimentary rocks.

Crossing over this intrusion, the limestone series was again encountered, the Hastings road for the next six miles passing over more or less continuous exposures of limestone, interstratified in places with a considerable volume of bedded amphibolites and fine-grained gneissic rocks which either represent intercalations of muddy sediments analogous to those forming the paragneisses about Millbridge, or have originated from the complete alteration of volcanic ashes which fell into the sea at certain times during the deposition of the limestones. The chemical composition of the majority of these amphibolites is such that they might be derived either from the alteration of calcareous silts or from showers of basic volcanic ashes. The existence of numerous gabbro intrusions, having a more or less rounded outline, in association with this limestone series, more especially where these amphibolite bands are abundant in it, suggests that these represent the bases of volcanic centers from the ejectamenta of which the amphibolites were derived.

Having gone north on the Hastings road as far as Murphy's Corners, the committee then proceeded to Gilmour, a station on the Central Ontario Railway about five miles to the east of the Hastings road, to examine certain conglomerates which are found in that vicinity associated with two bodies of granite which penetrate the limestone series.

The committee considered these conglomerates to be in part of autoclastic origin, and, in all probability, in part of volcanic origin, representing tufaceous material derived from volcanic centers now represented by the masses of granite associated with it. Dr. Barlow, however, who mapped the occurrence, considers them to be of exclusively autoclastic origin. The time at its disposal did not enable the committee to make a detailed examination of the stratigraphical relations of this conglomerate, but after the field-work of the committee was brought to a close, Messrs. Cushing and Adams returned to this locality and re-examined the conglomerates. They found that they were interstratified with limestones, and consequently of the same age as these rocks, and that, on approaching the granite mass lying to the east, these rocks were thrown into a series of very sharp folds, evidently due to their being pressed against the granite mass, and that the granite mass, immediately about its contact with these rocks, exerted a very pronounced exomorphic contact action, changing the limestones for a distance of at least 100 yards into a mass of reddish-green rock consisting of an admixture of epidote, garnet, pyroxene, and other minerals. The committee therefore considers this conglomerate to be of interformational origin, and to have no special structural significance.

The committee then proceeded by train to Ormsby, where they examined a remarkable development of the limestone series consisting of beds of limestone interstratified with thin bands of amphibolite, displaying a series of very intricate folds. They also examined the Thanet gabbro, a large intrusive mass of approximately circular outline which here breaks through the limestone series, sending dykes into it and including masses of the latter. They also visited the Coehill iron mines, situated about five miles to the west of the village of Ormsby, where a very considerable body of somewhat pyritiferous magnetite is developed in the limestones, here interstratified with amphibolite about the contact of an intrusive mass of syenite.

Between Ormsby and Ormsby Junction the committee saw a great development of the typical rusty gneiss which is so commonly associated with the white crystalline limestones wherever these occur in the area embraced by the work of the committee. The development of these gneisses at this locality is one of the thickest which have hitherto been discovered in this series. Some bands of it resemble in appearance certain varieties of the Magnetite-Grunerite Schist of the Lake Superior iron ranges.

From Ormsby Junction the party went north by railway, passing over a further extension of the limestone series to Bancroft on the York branch of the Madawaska River, and examined the nepheline syenites, which have a very extended development in this district, and which in one locality about two miles and a half on the east of Bancroft are traversed by veins containing large masses of sodalite which are now being worked for decorative purposes.

They then went east to Bronson's Landing and proceeded by canoes down the York. branch of the Madawaska to Craigmont, and spent three days in examining the very extensive and highly interesting occurrences of corundum which are here being mined on an extensive scale. This corundum occurs in syenites, most of which are rich in nepheline.

The party then returned to Bancroft and went by the Irondale, Bancroft & Ottawa Railway to Gooderham, stopping on the way to examine a large deposit of biotite, formerly worked at this point, and which occurs in a granular, green pyroxenite which represents an altered limestone, near Wilberforce station. The limestone band is here highly altered, owing to the fact that it lies between two great bathyliths of granite.

At Gooderham the committee studied the relation of the limestone series to one of the great bathylith intrusions which form the northern portion of the area mapped by F. D. Adams and A. E. Barlow. This, which is known as the Glamorgan bathylith, is here ten miles wide and is completely surrounded by the limestone series through which it breaks. They first examined the eastern margin of the bathylith. Starting from the normal development of the limestone series on the line between the townships of Glamorgan and Monmouth, they went westward toward the bathylith, following the Ursa road. They found the limestone series became penetrated by dykes of granite in ever-increasing numbers, becoming eventually torn into fragments which lay thickly scattered in the granite forming the margin of the bathylith. It was noted that the limestone on going toward the granite became progressively more impure, being apparently replaced by amphibolite, and that but few fragments of limestone could be found among the inclusions of the granite itself.

The committee then examined the southern contact of the bathylith in the railway cutting at Maxwell's Crossing on the Irondale, Bancroft & Ottawa Railway. Here they found undoubted evidence that the limestone was being changed by the granite, first into a rock composed of pyroxene, plagioclase feldspar, scapolite, and calcite, and then, when the action was more intense, by a further change into a gray amphibolite consisting of hornblende, pyroxene, and feldspar, the latter dominantly plagioclase. The committee are of the opinion that the evidence is indisputable that the granite bathyliths in this region change the invaded limestone into a dark-gray amphibolite, which, together with the fragments of the interbanded amphibolites found everywhere in the limestone series, occurs scattered throughout the granite mass in the form of included fragments. By this statement it is not meant to imply that all of the amphibolites of the district are derived from the metamorphism of limestones, for in some places the amphibolites appear to be metamorphosed pyroclastic material, and in other places they originate from the metamorphism of intrusive basic igneous rocks. One of the chief difficulties solved in the study of the district by Adams was the recognition of the fact that the amphibolites had such diverse origins.

In the vicinity of Gooderham the committee also examined a large occurrence of titaniferous iron ore representing a differentiation product of a large gabbro intrusion which occurs to the south of Gooderham. This iron ore is situated on lot 35 of Range IV of the township of Glamorgan. They also saw several occurrences of graphite in the limestone series in this vicinity and examined three occurrences of nepheline syenite which are here found penetrating the limestone series. These nepheline syenites hold in many places inclusions of calcite, often of microscopic dimensions, which are clearly fragments of the limestones in which the nepheline syenites occur.

Leaving Gooderham, the party went north across the entire width of the Glamorgan bathylith to Haliburton. They found the bathylithic mass to form an area of very rough country, unlike that underlain by the limestone series. They also found the bathylith to consist chiefly of a fine-grained reddish gneissic granite, very poor in iron magnesia constituents. This, however, contained almost everywhere numerous inclusions of several varieties of amphibolite which the committee believe can be clearly proved, as held by Adams and Barlow, to represent fragments of the invaded limestone series. In addition to these there are considerable bodies of a grayish gneiss, which are believed to represent amphibolite inclusions which have been entirely absorbed or dissolved by the granite magma. It was stated by Adams that throughout the whole great area to the north of the district examined by the committee the bathylithic masses of granite were filled with similar inclusions. He estimates that these bathyliths on an average consist of about 80 per cent. of the red granite, 10 per cent. of the gray gneiss, and 10 per cent. of amphibolite inclusions, resulting in the way above mentioned.

About Haliburton the committee found the limestone series appearing in great force, developed in some places as great cliffs of white marble. This limestone can be traced continuously around the east end of the bathylith to the Ursa road and to Maxwell's Crossing, where the committee formerly examined it. To the north of Haliburton it is flanked by another bathylithic mass similar to that just described.

In this connection it should be remarked that, while the sedimentary rocks of this district have been referred to as the limestone series, this name has been adopted because in this series limestone is the dominant rock. The limestone is, however, commonly impure, not infrequently passing into phases in which the non-calcareous sediments are important or even dominant. Locally the sediments were apparently of the nature of altered volcanic fragmental material. This heterogeneity of original composition naturally leads to very great variety in the metamorphosed products, which vary from gneiss through calcareous schists to marbles and several varieties of amphibolites.

At Haliburton the field-work of the committee was brought to a close.

III. RÉSUMÉ OF THE GEOLOGY OF THE ADIRONDACK AREA

So far as known, the oldest series of rocks in the Adirondack area consists of strongly and coarsely crystalline limestones, ophicalcites, quartzites, quartz-schists, rusty, micaceous, thinly foliated gneisses and more massive gneisses. Among these the limestones are on the whole the ones most easily recognized. On the east they are well and prominently developed. In the central area they seem to be extensive, but are poorly exposed, and quartz schists are prominent. On the northwest they appear in largest amount and form continuous belts over long distances. The limestones are usually charged with bunches and streaks of silicates, which are in part torn and sheared intrusives, in part pegmatites, and probably also in part former siliceous, ferruginous, aluminous bands.

The quartzites on the east are best developed near South Bay, one of the two southern arms of Lake Champlain. They are thoroughly recrystallized, and all original clastic structure has been destroyed. They may contain great proportions of feldspar, and may also have sufficiently large percentages of graphite to be mined for this mineral. These feldspathic varieties were doubtless originally shales.

Rusty micaceous rocks with a peculiar yellow color on exposed surfaces are also frequent, although not in great thickness. They and other schistose, micaceous gneisses are believed to be recrystallized sediments.

Beneath the above, and sometimes interstratified with them, are more massive gneisses of a general granitic composition. While quartz and feldspar are the principal minerals, dark silicates also appear of the following kinds: emerald-green augite, brown hornblende, and biotite. Several varieties of gneiss are known depending on the relative proportions of these minerals. The iron ores are associated with them in almost all cases. It is a doubtful point as to whether these gneisses are in any cases sediments. They may be mashed, intrusive, granitic rocks in which the foliation is secondary, or they may be extreme phases in the metamorphism of arkoses or acidic volcanic tuffs.

In the Adirondack Mountains the series is invaded by enormous bodies of intrusive rock (anorthosite, gabbro, syenite, etc.), so that the sedimentary portion of the series forms a relatively smaller proportion of the whole complex than in the other areas covered by the work of the committee.

The undoubted sediments and their associated gneisses of uncertain origin are penetrated by several varieties of plutonic eruptives. The oldest constitute the anorthosite series, and embrace rocks from aggregates of nearly pure plagioclase to fairly rich mixtures of augite, hypersthene, and ilmenite with the plagioclase. The borders of the great bathyliths tend to be more basic than the centers.

The next in time among the intrusives constitute the syenite series. The typical rocks consist of microperthite, augite, hornblende, biotite, and varying amounts of quartz. Subordinate varieties are as rich in quartz as typical granites. Near the contacts with anorthosites and limestones garnets become numerous.

The third eruptive series consists of typical granites of both hornblendic and micaceous varieties. Areally the granites are of small extent, but they appear in scattered exposures outside the anorthosites.

The fourth series consists of dark basic gabbros, which are certainly later than the others, except perhaps the granites. No intersections with the latter are known. The basic gabbros appear in wide distribution throughout the area, and form dikes, stocks, and small laccoliths.

All these intrusives preceded a great period of metamorphism. Following it and still antedating the Potsdam, there entered two series of narrow dikes: one of basaltic rocks, which are very widely distributed, and a minor set of syenite-porphyry.

The oldest Paleozoic sediment anywhere in the Adirondacks is the Potsdam sandstone.

From the above it is evident that in this area the pre-Cambrian formations are practically the same as those in the neighboring parts of Ontario and Quebec.

IV. RÉSUMÉ OF THE GEOLOGY OF THE EASTERN ONTARIO AREA

The area presents an immense development of highly metamorphosed rocks, for the most part of sedimentary origin. Among these limestones preponderate. These limestones in the southern portion of the area, where the metamorphism is less intense, are often fine in grain and drab or bluish in color. On going north, however, there is a progressive increase in the intensity of metamorphism, and the limestones gradually lose their color and become coarser in grain, eventually developing into coarsely crystalline white marbles, generally more or less impure.

Interstratified with these limestones are non-calcareous rocks, among which fine-grained, often more or less rusty weathering gneisses and a variety of amphibolites are the most important and the most abundant. A few bands of quartzite also occur, although in this area these are distinctly subordinate

These gneisses certainly represent highly altered and recrystallized sediments, more or less argillaceous in character. The quartzites are in the majority of instances altered arenaceous sediments. Adams has shown that the amphibolites have a threefold origin. Certain of them represent limestones which have been altered by invading granites; others have been produced by the dynamic alteration of basic igneous intrusions; while still others have in all probability resulted from the recrystallization of basic fragmental volcanic material. The remarkable fact is that all these processes produce amphibolites which cannot be distinguished from one another either by appearance or by chemical analysis. The discovery of their genetic relations affords the key to the solution of some of the most important problems presented by this and other similar areas.

The relative abundance of the limestones and their associated gneisses and amphibolites varies from place to place. In some parts of the area there are enormous developments of nearly pure limestones. Elsewhere these are very impure, while in some places there are great thicknesses of amphibolites and gneisses entirely free from limestones.

The limestones with their interstratified and bedded amphibolites are usually steeply inclined, although in certain parts of the area they keep a nearly horizontal attitude.

The thickness of the series cannot be determined, but it is very great. It is one of the thickest pre-Cambrian series in North America.

Along its whole northern border this sedimentary series is torn to pieces by an enormous volume of gneissic granite of igneous origin which rises from beneath it, and which along its margin also wells up through it in the form of great intrusive bathyliths. This is filled with included fragments of the invaded series, limestones altered to amphibolites, fragments torn from interstratified bands of amphibolite, or of sedimentary gneiss, being scattered through it everywhere and being sometimes found in a more or less digested condition.

The base of the series has nowhere been found. Wherever its lower surface can be seen, it rests on great masses of the gneissic granite, which are intrusive into it and which, as has been mentioned, rise through it in the form of bathyliths.

In addition to the granite intrusions, around the border of which in many places there are occurrences of nepheline syenite which afford one of the most interesting studies in the area, there are also several larger and a number of smaller intrusions of a basic gabbro and gabbro-diorite. These often show a wide range of magmatic differentiation.

There are also a few smaller intrusions of anorthosite in the western part of the area, but these are distinctly subordinate.

A few small intrusions of typical granite also occur, one of which in the township of Lake, forms the center of a development of acidic lavas and apparently represents the plutonic plug of an ancient volcano.

Whether these intrusions of gabbro antedate those of the granite cannot be determined with certainty, as the two sets of occurrences are not found in contact.

In Logan's original examination of the southern portion of the area he used the designation "Hastings series" for the less altered portion of the series, and the term "Grenville" for the more highly altered portion. He expressed the opinion, however, at the time, that the Hastings series in all probability represented the Grenville series in a less highly altered form.

V. RÉSUMÉ OF THE GEOLOGY OF THE "ORIGINAL LAURENTAIN AREA" AND ITS EASTERLY CONTINUATION IN THE DISTRICT TO THE NORTH OF THE ISLAND OF MONTREAL

It has been thought well to make reference here to the "Original Laurentian area" and to its easterly continuation to the north of the island of Montreal. The committee did not examine these districts, but the former was studied by Sir William Logan in the early years of the Canadian Survey, a map of it having been published in the atlas accompanying the report of the survey for 1863, while the latter district was studied by F. D. Adams, his report and map of it appearing in 1896. As the studies in these districts have played an important part in shaping the nomenclature adopted in the case of the pre-Cambrian rocks of eastern America, the committee requested Dr. Adams to prepare the following brief description of them.

The "Original Laurentian area" of Logan lies in the province of Quebec, on the north shore of the Ottawa River, between the city of Montreal and the city of Ottawa, and takes its name from the township of Grenville and the village of that name, which lie within it. The second area mentioned forms the continuation of this "Original Laurentian area" to the east, and embraces the district about St. Jerome and eastward nearly as far as the St. Maurice River. There is every reason to believe that the area embraced by these two districts represents the continuation of the pre-Cambrian series studied by the committee in eastern Ontario, seeing that both occupy precisely the same relative position along the southern margin of the protaxis and that rocks similar to them in petrographical character occur in the intervening tract of country. In the development of these rocks in the province of Quebec, however, the "Hastings" facies (see p. 201) is absent, the rocks being all highly altered, and resembling in this way those found in the Adirondack Mountains and in the more altered portion of the Ontario district.

The "Original Laurentian area" and its easterly continuation above mentioned, like the area in eastern Ontario, occupy the southern portion of the Laurentian peneplain, underlying a great tract of slightly undulating country. They are composed of great bands of limestone interstratified with amphibolite and rusty weathering gneiss, often highly garnetiferous. This rusty weathering gneiss, where it occurs typically developed in the district about St. Jean de Matha, is found to be rich in sillimanite and to have the chemical composition of an ordinary clay slate. Bands of quartzite are also present in a number of localities, being interstratified with the gneisses and limestones above mentioned. Limestone, however, is the dominant rock of the sedimentary series.

In Logan's "Original Laurentian area" this distinctly sedimentary series occurs in great folds, the horizons marked by the limestone bands, as mapped by Logan, striking across the country in a series of great sweeping curves. The large bodies of orthoclase gneiss which are present in the district and which Logan considered to form part of the sedimentary series, a more detailed examination in view of recent discoveries would probably show to belong to the lower igneous gneisses and to be of intrusive origin.

Farther east, in the district to the north of the island of Montreal the limestone series is not always so sharply folded, and in one portion of the district, over an area of about 750 square miles, it lies nearly flat, low quaquaversal dips being everywhere observed, the attitude of the beds suggesting that the whole series originally floated on a great body of the underlying granite gneiss. This farther north comes to the surface, the limestone series being torn to pieces by it, and the bathyliths thus emerging being traceable over great areas, the foliation of the gneiss presenting great sweeping curves to which the courses of the lakes and rivers in this northern country conform. It will, therefore, be seen that in all its features this development of these pre-Cambrian rocks in the province of Quebec conforms to those which have already been described from the areas visited by the committee.

In the eastern part of the original Laurentian area Logan found a large mass of anorthosite, which may be termed the "Morin anorthosite." This formed the eastern limit of the area which he mapped. This anorthosite he found to be in some places more or less distinctly foliated, which foliation he regarded as a survival of an almost obliterated bedding. He furthermore found that the limestone bands in the sedimentary series disappeared on coming against this mass of anorthosite. From these two facts he concluded that the anorthosite belonged to an unconformable, although highly metamorphosed, sedimentary series, which unconformably overlay the Grenville series, whose limestones he considered to pass beneath the anorthosite mass.

Adams, in continuing Logan's work to the east, had occasion to map and thoroughly study this anorthosite body. He found it to have the shape of a clover leaf and to have an area of 990 square miles. The anorthosite in the central portion, and over the greater part of the western half of the mass, is nearly massive, although often showing an indistinct brecciated structure. On going from the center of the mass toward its eastern boundary, however, this brecciated structure becomes more and more pronounced, the angular fragments being imbedded in a progressively larger amount of granulated ground-mass, while along the eastern border the mass becomes perfectly foliated, the angular fragments disappearing almost entirely. These angular fragments and the ground-mass are identical in composition, both being composed essentially of plagioclase. The fragments represent portions of the original coarsely crystalline rock in an uncrushed condition, the ground-mass being produced by the granulation and breaking-down of the original rock, of which the brecciated fragments are the surviving remnants. The fragments in the breccia, like the rock when in a massive form, are deep-blue in color, while the granulated rock has lost this blue color and is gray, sometimes nearly white. This is due to the disappearance of the minute inclusions so abundant in the plagioclase feldspar of all these anorthosites which have not been crushed. Where the rock becomes perfectly foliated, as along the eastern border of the anorthosite mass, and especially in the narrow extension running off from the southern part of the area and representing the stalk of the clover leaf, the rock becomes perfectly white in color, so closely resembling a saccharoidal marble that the two can be distinguished only on making a trial of their hardness.

A detailed stratigraphical study of this mass proved undoubtedly that it was an igneous intrusion which had broken through the Grenville series, cutting off the limestone bands of the latter instead of covering them up, and which had been subsequently granulated by great pressure brought to bear upon the whole region from the east, seeing that it is on that side that the mass is most intensely granulated, while on the west granulation is confined to the immediate border of the mass.

With regard to the petrographic character of this anorthosite, it may be stated that it is composed almost exclusively of labradorite; augite, hypersthene, and a little iron ore being the other constituents. It is identical in character with most of the other anorthosite masses in the Laurentian of Canada. Hunt, in his early investigations of these rocks, stated that three-quarters of the anorthosite ooccurrences in Canada did not hold over 5 per cent. of minerals other than plagioclase.

It is to be noted that the foliation of the anorthosite, which is a secondary structure due to pressure, was already completed in pre-Potsdam times, for the perfectly foliated rock is overlain by horizontal beds of the sandstone in question.

In addition to this great intrusion of anorthosite, there are twelve smaller intrusions similar in character occuring in the area mapped by Adams.

In addition to these anorthosite intrusions, the sedimentary series, in the original area and in its extension to the east, is penetrated by several intrusions of more acid rocks. One of these consists of a mass of syenite which occurs in the township of Grenville and has an area of about thirty square miles, which is in its turn penetrated by a small body of feldspar porphyry, sometimes holding a small amount of quartz.

Another acid intrusion is represented by the great body of granite, in places developed in the form of coarse augen gneiss, which occurs about twenty-five miles to the east of the Morin anorthosite intrusion. This possesses the ordinary character of such granitic rocks.

More especially in the southern portion of the "original Laurentian area" there also occur a great number of basic dikes, consisting for the most part of diabase, which represent, as a general rule, the latest intrusions of the district, and which persist across the front of the whole area from west of Grenville to a point north of the island of Montreal, where they disappear beneath the Ordovician cover. These diabase dikes were, however, considered by Logan to be older than the intrusion of syenite in the Grenville district already mentioned, which, in its turn, was older than the porphyry intrusion which cut it. While, therefore, in this original Laurentian area and its eastward extension there is not so great a relative proportion of rocks which are clearly of intrusive origin as in the case of the Adirondack area, intrusive rocks in very considerable variety and of the same general types are represented.

It is worthy of mention that in the Laurentian protaxis still farther to the east, in the district to the north of the Gulf of St. Lawrence and in the Labrador peninsula, a number of anorthosite intrusions of gigantic extent occur. Among these may be mentioned more especially one which may be referred to as the "Saguenay anorthosite," on account of the fact that it is developed about the head waters of this river. This, which resembles the Morin anorthosite in character, has an area of not less than 5,800 square miles. Another enormous area is traversed by the Moisie River, the Clearwater, a tributary of the Moisie, running through a great canyon in this anorthosite. Still others of similar extent might be mentioned. The occurrences of anorthosite which are now known to exist in the Labrador peninsula represent a total area of nearly 50,000 square miles.

As a result of his studies in the Grenville region, Logan announced his belief that the Laurentian system consisted of two great unconformable series of sedimentary rocks, to which he gave the names "Upper Laurentian" and "Lower Laurentian." The latter he considered to be again divisible into a lower and upper portion, which subdivisions he considered to be probably conformable to one another. In the course of time these several series came to be known respectively as the "Anorthosite" or "Norian" series, the "Grenville" series, and the "Fundamental" or "Ottawa Gneiss." Logan's classification may thus be represented as follows:

Upper Laurentian		Anorthosite or Norian Series
Lower Laurentian	Upper Portion	Grenville Series
	Lower Portion	Fundamental or Ottawa Gneiss

The subsequent investigations by Adams in the district to the east of that studied by Logan showed that the Anorthosite (or Logan's Upper Laurentian series) really consisted of great intrusions, and that the associated limestones, etc., assigned by Logan to the "Upper Laurentian" were really part of the Grenville series. There therefore exist in these pre-Cambrian areas of the province of Quebec two divisions, namely, the Grenville series and the underlying Fundamental Gneiss. The relations of these have not been worked out in such detail as in the case of the Ontario area, but it is believed that here also the Fundamental Gneiss comes against the Grenville series with an intrusive contact.

VI. RECOMMENDATIONS OF THE COMMITTEE CONCERNING CORRELATION AND NOMENCLATURE

The committee considers that over the whole area covered by their investigations—namely, the Adirondack Mountains, that portion of eastern Ontario which they examined, the "original Laurentian area" in the province of Quebec and its continuation to the east as far as the river St. Maurice—the pre-Cambrian sedimentary development is represented by one great series. This series is essentially identical in petrographical character throughout the whole region.

The only locality where the possible (Coleman would say probable) existence of a second uncomformable sedimentary series was suggested by the facts observed, was that on the Queensboro road, east of Madoc, Ontario. It is, however, still a matter of uncertainty as to whether the conglomerate here developed marks the base of an overlying, infolded, uncomformable series or not.

In Logan's original classification of the Laurentian this term—apart from the Upper Laurentian which was proved to be composed essentially of anorthosite intrusions—included two series differing in character, namely, the Lower Orthoclase (Fundamental) Gneiss and the Grenville series. Now that investigations have shown that these two series differ in origin, one being essentially a great development of very ancient sediments, and the other consisting of great bodies of igneous rock intruded through them, it becomes necessary to separate these two developments in drawing up a scheme of classification.

As the great intrusions of gneissic granite, forming what has been termed the "fundamental gneiss," have an enormously greater areal development than the overlying sedimentary series, constituting, as they do, a very large part of the whole northern protaxis, the committee recommend that the term "Laurentian" be restricted to this great development of igneous gneisses. The nomenclature suggested for the pre-Cambrian rocks of this eastern region will thus conform, so far as the use of this term is involved, with that suggested by the Special Committee for the Lake Superior region.[1]

For the overlying sedimentary series the committee recommend the adoption of the name "Grenville series," as it is the name originally given by Logan to the series as typically developed about the township of Grenville in the "Original Laurentian area" on the north shore of the Ottawa River, in the Province of Quebec, between the cities of Montreal and Ottawa. The term "Hastings series" in the opinion of the committee should be abandoned as a serial name, seeing that the development to which this name was applied by Logan is merely the Grenville series in a less altered form, as Logan in giving the name had conjectured was probably the case. The committee, however, think that it may in some cases be advantageously employed as a qualifying term to designate the less highly altered phase of the Grenville series, which may thus be referred to as the "Hastings phase" of the Grenville series.

In Canada this Grenville series everywhere on going north is invaded by and frays away into the great Laurentian bathyliths, while in the Adirondacks it is cut to pieces by the great intrusions of that area which, when worked out in detail, may prove also to have a more or less similar bathylithic form.

The following succession in this region is therefore recognized and adopted by the committee:

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[1] See *Journal of Geology*, February–March, 1905.

Cambrian—Potsdam sandstones, etc.
  (Unconformity)
Pre-Cambrian
  Grenville series
    (Intrusive contact)
Laurentian

The committee consider that it is inadvisable in the present state of our knowledge to attempt any correlation of the Grenville series with the Huronian or Keewatin, so extensively developed in the region of the Great Lakes. The Grenville series has not as yet been found in contact with either of these, and until this has been done and the relations of the several series have been carefully studied, their relative stratigraphical position must remain a mere matter of conjecture.

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